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TITLE: HOTMAC Input Guide

**AUTHOR(S): Michael J. Brown, TSA-4
Mike Williams, TSA-4**

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**Los Alamos National Laboratory
Los Alamos, New Mexico 87545**

HOTMAC Input Guide

Definitions, Format, and Examples of the HOTMAC Input File

DRAFT

Michael Brown and Mike Williams
Los Alamos National Laboratory
Energy and Environmental Anaysis, Group TSA-4

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1. HOTMAC Input File Format

a. Introduction.

This guide is intended to give updated information on the input necessary to run the current version of the prognostic mesoscale meteorological model HOTMAC (Higher-Order Turbulence Model for Atmospheric Circulation). The current version of HOTMAC (**tsa4_hotmac_v3.2**) used by LANL's Energy and Environmental Analysis Group TSA-4 has a two-stream solar radiation approximation, a multiple nudge profile capability, and a time-varying geostrophic wind input capacity. A user's manual describing the physics and numerics of the code is available (Williams et al., 1989), as well as many peer-reviewed articles (e.g., Mellor and Yamada, 1974; Yamada and Bunker, 1989; Williams et al., 1995).

b. Format and Definitions.

The current version of HOTMAC requires one input file containing information on grid parameters, simulation times, initial meteorological fields, nudging constants, numerical scheme coefficients, short and longwave radiation parameters, as well as gridded data for the elevations and land classes of the underlying topography. The file, typically named ***hot_in.”description_of_simulation”***, is described below.

The file begins with nine namelist categories called:

- nest (nested grid parameters)
- grid (grid parameters)
- times (simulation start time and print time parameters)
- init (met. field initialization parameters)
- canopy (urban and forest canopy parameters)
- param1 (various input parameters)
- param2 (numerical scheme parameters)
- add (parameters for added layer aloft used for longwave radiation computations)
- nudge (nudge profile parameters)

The namelist format allows for comments to be added between input data fields, without coding for the comment lines in the HOTMAC program. However, the namelist format

can be different for different Fortran compilers (e.g., the “\$” -- denoting the beginning and ending of a namelist category -- might be replaced with a “&” in another compiler). Figures 1.1 to 1.3 show the format of the beginning of the HOTMAC input file.

```

# HOTMAC INPUT FILE FOR tsa4_hotmac_2s_ep4.f
#
#      ** EL PASO AREA SIMULATION **
#
#
# -----
# NESTED GRID PARAMETERS
# -----
#
#      ngmax      = number of grid meshes
#      grid_ratio = grid size ratio between nested meshes
#      utmx,utm = SW corner in utm coordinates (km) of grids (outer grid first)
#
$nest      ngmax=3,grid_ratio=3.0,utm=230,266,338,utm=3450,3468,3498
$end
#
# -----
# GRID PARAMETERS
# -----
#
#      imax      = number of grid cells in E-W direction (ngmax values - starting w/ outer grid)
#      jmax      = number of grid cells in N-S direction (ngmax values - starting w/ outer grid)
#      kmax      = number of grid cells in vertical direction (same for all grid meshes)
#      ksmax     = number of soil layers
#      ktrans    = no. of grids with smallest vertical resolution (dz defined by dzdksi)
#      clong     = approx. longitude of grid mesh center - used in [asolar] (ngmax values)
#      clat      = approx. latitude of grid mesh center - used in [asolar] (ngmax values)
#      xintvl   = x grid cell sizes (m) (largest grid only)
#      yintvl   = y grid cell sizes (m) (largest grid only)
#      dzdksi   = grid resolution in the surface layer (no. of grids = ktrans)
#      zkmaxpl  = maximum height in the terrain following coordinate (m)
#
$grid      imax=14,27,21,jmax=17,30,24,kmax=15,ksmax=5,ktrans=5,
           clong=106.5,106.5,106.5,clat=32.5,32.1,31.8,
           xintvl=18000.0,yintvl=18000.0,dzdksi=4.0,zkmaxpl=4000.0
$end
#
# -----
# SIMULATION START TIME AND PRINT TIME PARAMETERS
# -----
#
#      day0      = starting day of simulation (julian)
#      alst      = simulation start hour - local standard time (hours)
#      delgmt   = time difference between gmt and lst (hrs)
#      irept     = number of time steps in simulation for largest grid
#      deltma   = maximum time step for outermost grid (s)
#      isdump    = number of dump to read for restart
#                  = 0 initial run
#                  > 0 restart
#      iprint_int = i increment for printing (ngmax values)
#      jprint_int = j increment for printing (ngmax values)
#      kprint_int = k increment for printing
#
$times      day0=252.0,alst=18.,delgmt=6.0,irept=1000,deltma=666.,isdump=0,
           iprint_int=6,6,6,jprint_int=3,3,3,kprint_int=1
$end

```

Figure 1.1. Beginning of the HOTMAC input file **hot_in** illustrating the format. Note that the namelist format allows any number of comment lines to be added without recoding the read statements in the HOTMAC Fortran program.

```

#
# -----
# MET. FIELD INITIALIZATION PARAMETERS
# -----
#
#      psea      = pressure at the mean sea level (mb)
#      temp_sfc   = real temperature (deg. C) at sfc. at nudge station location.
#                  From this, the potential temp. at the nudge station is computed.
#                  Then ptemp_msl, the potential temperature at mean sea level,
#                  is derived from ptemp_sfc by extrapolating to mean sea
#                  level using the potential temp. gradient tgammal
#      twater     = water temperature (deg. C)
#      tgammal    = lapse rate in the lowest layer (sfc to elevinv1) (deg. C/m)
#      tgamma#    = lapse rate between elevinv#-1 and elevinv# (deg. C/m)
#      tgamma6    = lapse rate above elevinv5 (deg. C/m)
#      elevinv#   = height at which initial temp. specified
#                  (when read in, measured relative to surface (m), but then converted to msl)
#                  (sfc < elevinv1 < elevinv2 < elevinv3 ... )
#      rhinit0    = initial relative humidity at surface
#      rhinit#    = initial relative humidity at ht. elev_rh#
#                  (intermediate rh values linearly interpolated between each specified value)
#      rhinit6    = rh at top of model domain
#      elev_rh#   = height at which initial rh specified
#      utmx,utmyi = location of initial met. profile in utm coordinates (km)
#      zsitei     = ht.of surface above mean sea-level at location of initial met. profile (m)
#
$init
psea=1100.0,temp_sfc=34.2,twater=15.0,
tgammal=-0.0258,tgamma2=0.00008,tgamma3=0.0031,
tgamma4=0.0014,tgamma5=0.0101,tgamma6=0.0037,
elevinv1=65.,elevinv2=2710.,elevinv3=3625.,elevinv4=4360.,elevinv5=4860.,
rhinit0=0.20,rhinit1=0.55,rhinit2=0.47,rhinit3=0.68,
rhinit4=0.94,rhinit5=0.33,rhinit6=0.32,
elev_rh1=2750.,elev_rh2=3000.,elev_rh3=3300.,elev_rh4=4350.,elev_rh5=4600.,
utmxi=349.,utmmyi=3519.,zsitei=1200.
$end
#
# -----
# URBAN AND FOREST CANOPY PARAMETERS
# -----
#
#      drag      = drag coefficient of canopy
#      drgmax    = maximum value of drag coefficient
#      htree     = height of canopy (m)
#      treez1    = normalized height of canopy base
#      treez2    = normalized height of dead branch base
#      atree     = fractional tree or building coverage
#      excoef    = extinction coefficient
#      almax     = maximum leaf surface area density (1./m)
#      asmax     = maximum non-leaf surface area density (1./m)
#      bratio    = bowen ratio in canopy
#      qurb      = urban canopy anthropogenic heat input
#
$canopy
drag=.012,drgmax=.05,htree=22.0,treez1=0.01,treez2=0.005,
atree=1.0,excoef=6.5,almax=0.0,asmax=1.00,bratio=1.0,qurb=20.
$end

```

Figure 1.2. Continuation of the HOTMAC input file ***hot_in*** illustrating the format of the namelist input parameters.

```

#
# -----
# VARIOUS INPUT PARAMETERS
# -----
#
#      optpwv = optical depth of water vapor
#      albedot = tree albedo
#      bowmax = maximum bowen ratio
#      bowmin = minimum bowen ratio
#      edmax = maximum eddy viscosity (m**2/s)
#      edmin = minimum eddy viscosity (m**2/s)
#      constr = constant to approximate fraction of cloud coverage curve
#      ishade = flag for shadow calculation (not used)
#
$param1
      optpwv=0.3,albedot=0.2,bowmin=-10.0,bowmax=10.0,
      edmin=2.0e-5,edmax=500.,constr=0.8,ishade=0
$end
#
# -----
# NUMERICAL SCHEME PARAMETERS
# -----
#
#      smooth = computational smoothing factor (to remove 2-delta waves)
#      tolera = tolerance value for finding vertical velocity in [wwind]
#      relax = relaxation factor used in [wwind]
#      nlimit = max. iterations allowed in computation of vertical velocity [wwind]
#
$param2
      smooth=0.3,tolera=0.025,relax=0.30,nlimit=2500
$end
#
# -----
# PARAMETERS FOR ADDED LAYER ALOFT USED FOR LONGWAVE RADIATION COMPUTATIONS
# -----
#
#      kadd    = number of cells to add to top of domain in [radlon]
#      delzr   = grid spacing (m) in added zone (kadd values)
#      dtdzadd = temperature increment in added layers (deg/m)
#      dqdzadd = water vapor increment in added layers (g/kg/m)
#      qminadd = minimum water vapor allowed in added layers (g/kg/m)
#      topradf = radiation flux at top of added zone (watts/m**2)
#
$add
      kadd=5,delzr=10*1000.,dtdzadd=0.0033,dqdzadd=-0.007,qminadd=1.0,
      topradf=80.
$end
#
# -----
# NUDGE PROFILE PARAMETERS
# -----
#
#      gnudge     = nudging coefficient (set to zero to turn off nudging)
#      num_ndg_sites = no. of locations that nudge wind profiles are specified (up to 10)
#      sigx_ndg0   = the parameter that controls the horizontal E-W distance of
#                   influence of the nudging terms gfacuij and gfacvij at
#                   ground level. It is the standard deviation of a Gaussian
#                   distr. (km)
#      sigx_ndg1   = the parameter that controls the horizontal E-W distance of
#                   influence of the nudging terms gfacuij and gfacvij at the
#                   domain top. It is the standard deviation of a Gaussian
#                   distr. (km)
#      sigy_ndg0   = the parameter that controls the horizontal N-S distance of
#                   influence of the nudging terms gfacuij and gfacvij at
#                   ground level. It is the standard deviation of a Gaussian
#                   distr. (km)
#      sigy_ndg1   = the parameter that controls the horizontal N-S distance of
#                   influence of the nudging terms gfacuij and gfacvij at
#                   ground level. It is the standard deviation of a Gaussian
#                   distr. (km)
#
$nudge
      gnudge=.0004,num_ndg_sites=2,
      sigx_ndg0=2.,sigx_ndg1=200.,sigy_ndg0=2.,sigy_ndg1=200.
$end

```

Figure 1.3. Continuation of the HOTMAC input file **hot_in** illustrating the format of the namelist input parameters.

In the remaining sections of the ***hot_in*** input file, the number of comment lines must not change from what is shown below. The data, however, is read in with the Fortran `read(*,*)` statement, so that any format and spacing of data is acceptable.

The next section of the ***hot_in*** input file contains the utm coordinates, measurement times, and the wind measurements for each specified nudge site (as indicated by the parameter `num_ndg_sites` in the “nudge” namelist category). In the example shown, two sites are included in the input file (fig. 1.4). If `num_ndg_site` is less than 2, then the 21 lines associated with each nudge site should be deleted in ***hot_in***. If `num_ndg_site` is greater than 2, then for each additional site, 21 lines should be added.

```

#
# -----
# NUDGE SITE 1 COORDINATES - utmxn(km), utmyn(km), z_ndgsite (m_asl)
# -----
#
#           349.   3519.   1200.
#
# NO. OF TIMES THAT MEASURED (NUUDGE) WINDS ARE SPECIFIED AT SITE 1
#
#           8
#
# LST TIME OF MEASUREMENTS (t_ndg) AT SITE 1
#
#           18.      29.      41.      53.      65.      77.      89.      101.
#
# NUDGE WINDS AT SITE 1 - Z(m_asl), WS(m/s), WD(deg.) (zobs, wsobt, wdobt)
#
#           2500.   4.0    20.    3.0    15.    3.0   280.    2.0   180.    4.0    90.    5.0   150.    3.0    80.    3.0   170.
#           3250.   4.3    20.    4.0    70.    2.5   300.    4.0   270.    4.0    60.    5.0   110.    1.0    70.    2.0   100.
#           4000.   6.0    0.     5.0    80.    1.5   240.    2.0   265.    2.0    80.    5.0    95.    3.0   330.    6.0   160.
#           5000.   4.8    10.   3.0   330.    2.5   270.    3.0   310.    3.0   250.    2.0   120.    2.0   100.   9.0   200.
#
# -----
# NUDGE SITE 2 COORDINATES - utmxn(km), utmyn(km), z_ndgsite (m_asl)
# -----
#
#           365.   3533.   1100.
#
# NO. OF TIMES THAT MEASURED (NUUDGE) WINDS ARE SPECIFIED AT SITE 2
#
#           8
#
# LST TIME OF MEASUREMENTS (t_ndg) AT SITE 2
#
#           18.      29.      41.      53.      65.      77.      89.      101.
#
# NUDGE WINDS AT SITE 2 - Z(m_asl), WS(m/s), WD(deg.) (zobs, wsobt, wdobt)
#
#           2500.   2.0    20.    3.0    15.    3.0   280.    1.0   180.    2.0    90.    4.0   150.    2.0    80.    2.0   170.
#           3250.   3.3    20.    3.0    70.    3.5   300.    3.0   270.    3.0    60.    4.0   110.    2.0    70.    3.0   100.
#           4000.   6.0    0.     5.0    80.    1.5   240.    2.0   265.    2.0    80.    5.0    95.    3.0   330.    6.0   160.
#           5000.   4.8    10.   3.0   330.    2.5   270.    3.0   310.    3.0   250.    2.0   120.    2.0   100.   9.0   200.

```

Figure 1.4. Continuation of the HOTMAC input file ***hot_in*** illustrating the format of the nudge wind input parameters. Note that the number of comment lines must not be changed from that shown above.

```

#
# -----
# GEOSTROPHIC WINDS
# -----
#
# NO. OF TIMES THAT UPPER-LEVEL (GEOSTROPHIC) WINDS ARE SPECIFIED (AT LEAST ONCE ... USED FOR IC'S)
#
#          8
#
# UPPER-LEVEL (GEOSTROPHIC) WIND  (LST TIME, WD, WS) -> (t_geo, wd_geo, ws_geo)
#
17.0    5.   5.5
29.0    30.   4.0
41.0   255.   2.5
53.0   290.   3.0
65.0   150.   3.0
77.0   120.   3.5
89.0    60.   2.0
101.0   180.   7.5
#
# -----
# LOCAL WINDS
# -----
# (COMPUTED W/ NO LARGE SCALE FORCING) (WD, WS) -> (wdnull, wsnnull)
# READ IN CONSECUTIVELY FROM HOURS 1-24 LST
#
262.   0.0
261.   0.0
261.   0.0
260.   0.0
260.   0.0
262.   0.0
268.   0.0
271.   0.0
272.   0.0
272.   0.0
271.   0.0
271.   0.0
270.   0.0
270.   0.0
269.   0.0
268.   0.0
268.   0.0
267.   0.0
265.   0.0
264.   0.0
263.   0.0
263.   0.0
263.   0.0
262.   0.0

```

Figure 1.5. Continuation of the HOTMAC input file ***hot_in*** illustrating the format of the geostrophic and local wind input parameters. Note that the number of comment lines must not be changed from that shown above.

The next section of the HOTMAC input file ***hot_in*** contains the geostrophic winds and local winds (fig. 1.5). The geostrophic wind needs to be specified at least once, as the initial geostrophic wind is used as the upper b.c. in the determination of the initial wind profile. The first value of *t_geo*, therefore, should be close to the model start time *alst*. Note: if the geostrophic wind changes direction rapidly with time, we recommend running the model with nudging turned on (at least in the upper layers) in order to remove inertial oscillations.

The local winds are used to adjust the measured nudge winds near the surface in order to separate the “locally” produced wind from the “large-scale” wind. The local winds are produced by running the HOTMAC model without any large-scale forcing ($ws_geo = 0.0$) and with nudging turned off ($gnudge = 0.0$) and then averaging the model-produced winds over some user-specified depth. To run the model without a local wind correction, simply set $wsnull = 0.0$.

The landclass specification, elevations, and soil depth layers are found next (fig. 1.6 to 1.8). The data is organized by grid mesh, with the outermost grid coming first and the innermost grid coming last. Five comment lines are included at the beginning of each grid mesh section and should not be changed. The landclass and elevation data are input in text matrix format of size $imaxp1 \times jmaxp1$ and $(imaxp1 + 2) \times (jmaxp1 + 2)$, respectively, where $imaxp1 = imax + 1$ and $jmaxp1 = jmax + 1$. The landclass and elevation formats are discussed in more detail in Sections 2 and 3. The soil depth layers are in meters below ground level and are generally not changed from simulation to simulation.

```

# -----
# OUTER GRID 1    # LAND CLASS: N - TOP, S - BOTTOM (imaxp1 x jmaxp1)
# -----          # ELEVATION (M): N - TOP, S - BOTTOM (imaxp1+2 x jmaxp1+2)
#
6 6 12 6 12 6 6 6 6 6 6 6 6 6 6
6 6 12 6 6 6 6 6 6 6 6 6 6 6 6
6 12 6 12 6 6 6 6 6 6 6 6 12 12 12
12 12 6 6 6 6 6 6 6 6 6 6 12 12 12 6
12 12 6 6 6 6 6 6 6 6 6 6 12 12 12 6
12 6 6 6 6 6 6 6 6 6 6 6 6 12 12 12 6
12 6 6 6 6 6 6 6 6 2 6 6 12 12 12 6
6 6 6 6 6 6 6 6 2 6 6 12 12 12 6
6 6 6 6 6 6 6 6 6 6 6 6 12 12 12 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
2109 2109 2139 2260 2260 2197 1617 1536 1563 1705 1949 1780 1880 2000 1853 1664 1516
2151 2151 1944 2426 2060 2197 1617 1536 1563 1705 1949 1780 1880 2000 1853 1664 1516
2382 2382 2230 2370 1962 1645 1473 1485 1486 1854 1837 1687 1922 2014 1820 1649 1514
2319 2319 2175 2198 2035 1470 1422 1444 1455 1742 1528 1601 1944 2099 2173 1786 1496
2250 2354 2157 1906 1713 1474 1445 1486 1588 1445 1397 1759 2490 2066 1887 1716 1519
2220 2463 2063 1756 1493 1444 1502 1830 1716 1289 1318 1686 2324 2236 1989 1715 1559
2327 2507 2017 1669 1401 1461 1516 1857 1365 1227 1276 1543 2268 2362 2029 1761 1578
1980 2292 2084 1602 1447 1561 1423 1659 1417 1205 1248 1465 2412 2364 1987 1705 1528
1890 1870 1944 1556 1436 1438 1358 1471 1488 1204 1227 1466 2645 2355 2016 1693 1524
1633 1655 1716 1493 1377 1363 1326 1360 1594 1216 1213 1266 2006 2219 1919 1756 1610
1449 1479 1546 1403 1472 1504 1330 1357 1602 1218 1266 1281 1573 1695 1722 1603 1870
1387 1367 1319 1291 1365 1380 1309 1286 1634 1225 1254 1367 1548 1417 1429 1297 1382
1323 1307 1396 1257 1285 1339 1286 1210 1296 1231 1266 1480 1560 1461 1332 1250 1210
1391 1316 1314 1233 1339 1382 1277 1220 1300 1227 1281 1603 1547 1541 1309 1156 1107
1410 1319 1288 1220 1285 1293 1261 1239 1264 1203 1271 1540 1526 1389 1307 1158 1102
1522 1302 1266 1218 1208 1240 1241 1247 1283 1140 1220 1346 1474 1403 1286 1229 1145
1274 1354 1241 1210 1193 1204 1222 1247 1236 1186 1141 1222 1409 1479 1354 1368 1475
1289 1376 1347 1203 1262 1186 1206 1233 1286 1359 1197 1127 1204 1391 1423 1453 1578
1296 1389 1425 1256 1263 1216 1185 1221 1307 1445 1354 1377 1104 1280 1421 1437 1552
1317 1341 1605 1240 1252 1256 1179 1227 1355 1427 1466 1542 1256 1134 1330 1341 1352
0.0000000E+00 0.8985154E-02 0.5360211E-01 0.1590036E+00 0.3029266E+00
0.0000000E+00 0.3047725E-02 0.2389413E-01 0.9965295E-01 0.2277447E+00

```

Figure 1.6. Continuation of the HOTMAC input file **hot_in** illustrating the format of the landclass, elevation, and soil depth input parameters.

Figure 1.7. Continuation of the HOTMAC input file *hot_in* illustrating the format of the landclass, elevation, and soil depth input parameters.

The last input data in the ***hot_in*** file (fig. 1.9) is for the two-stream solar radiation approximation that has been incorporated into the latest version of HOTMAC. This data should, in general, not be changed from simulation to simulation. More information on the two-stream approximation and parameter definitions can be found in Smith and Kao (1996).

```

#
# -----
# INNER GRID 3      # LAND CLASS: N - TOP, S - BOTTOM (imaxpl x jmaxpl)
# -----          # ELEVATION (M): N - TOP, S - BOTTOM (imaxpl+2 x jmaxpl+2)
#
6 6 11 11 11 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 11 11 11 11 6 6 6 6 6 6 6 6 6 6 6 6 6 6 2 9 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 11 6 6 6 6 6 6 6 6 6 6 6 6 6 2 2 2 6 6 6 6 6 6 6
6 6 6 11 11 11 9 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 11 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 9 6 6 6 4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 9 2 6 6 6 6 6 6 6 6 6 6 6 9 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 9 6 6 6 6 6 4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 6 6 6 6 6 6 6 6 6 6 4 6 9 6 9 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 11 11 11 2 6 6 6 6 6 6 6 6 6 6 6 6 6 9 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 11 11 2 2 6 6 6 6 6 6 9 6 9 6 9 6 9 9 6 6 6 6 6 6 6 6 6 6 6
6 6 6 2 9 9 9 2 9 9 6 6 9 6 9 9 6 9 6 9 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 9 9 9 9 6 6 6 6 9 9 9 9 9 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 9 9 2 9 6 9 9 9 9 9 9 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 2 6 2 9 6 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 9 9 9 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 6 6 6 6
6 6 6 6 6 6 6 6 6 6 9 9 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 2 6
6 6 6 6 6 6 6 6 6 6 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 2 6
6 6 6 6 6 6 6 6 6 6 9 9 9 9 9 9 9 9 9 6 6 6 6 6 6 6 6 6 6 6 2 6
6 6 6 6 6 6 6 6 6 6 9 6 9 9 9 9 9 9 9 6 6 6 6 6 6 6 6 6 6 6 9 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 11 9
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 11 9
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 11 11
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
1253 1217 1175 1162 1160 1163 1190 1225 1260 1334 1286 1278 1264 1244 1242 1250 1244 1238 1227 1219 1218 1233 1241 1243
1259 1246 1201 1160 1158 1158 1169 1209 1238 1361 1362 1292 1280 1258 1239 1240 1239 1239 1231 1222 1218 1227 1239 1241
1259 1249 1210 1159 1157 1157 1164 1199 1229 1303 1380 1314 1294 1271 1243 1231 1234 1236 1232 1223 1213 1226 1235 1237
1262 1253 1219 1157 1150 1150 1154 1187 1233 1323 1378 1437 1365 1293 1249 1231 1234 1235 1232 1223 1216 1225 1236 1239
1263 1255 1214 1156 1144 1138 1154 1185 1224 1301 1426 1506 1385 1303 1249 1232 1235 1229 1222 1216 1228 1237 1238
1260 1254 1225 1162 1150 1141 1144 1187 1237 1298 1423 1682 1484 1307 1246 1227 1230 1231 1225 1220 1217 1225 1235 1238
1258 1254 1228 1172 1153 1143 1142 1190 1248 1315 1420 1746 1477 1301 1247 1222 1218 1222 1218 1217 1220 1222 1230 1235
1254 1251 1239 1175 1154 1143 1141 1186 1243 1323 1423 1675 1423 1309 1244 1217 1206 1209 1213 1215 1218 1221 1226 1233
1256 1253 1225 1174 1155 1144 1138 1181 1241 1315 1435 1717 1503 1327 1236 1213 1201 1203 1210 1214 1217 1220 1224 1231
1255 1253 1225 1177 1155 1145 1137 1169 1235 1317 1452 1841 1626 1353 1229 1201 1196 1202 1209 1216 1218 1220 1223 1229
1254 1253 1246 1190 1158 1147 1136 1168 1222 1298 1403 1622 1544 1321 1211 1190 1193 1202 1206 1213 1221 1219 1220 1225
1253 1254 1246 1198 1170 1150 1137 1158 1220 1285 1373 1688 1524 1303 1201 1185 1193 1201 1204 1211 1219 1219 1219 1222
1251 1254 1248 1223 1187 1163 1139 1151 1193 1247 1330 1577 1457 1276 1198 1182 1192 1199 1204 1210 1216 1219 1220 1222
1248 1250 1254 1246 1237 1203 1151 1141 1166 1210 1279 1566 1441 1271 1186 1181 1193 1199 1201 1210 1216 1220 1220 1221
1244 1247 1251 1255 1250 1238 1208 1143 1141 1157 1220 1389 1434 1223 1175 1184 1200 1204 1203 1210 1217 1221 1220 1222
1244 1243 1247 1251 1252 1253 1244 1189 1174 1208 1164 1248 1307 1163 1162 1188 1197 1203 1204 1209 1216 1218 1221 1221
1246 1240 1243 1246 1248 1251 1263 1251 1231 1210 1153 1155 1130 1130 1141 1159 1192 1204 1206 1215 1213 1221 1221
1245 1239 1240 1243 1246 1252 1277 1265 1240 1212 1175 1143 1133 1129 1127 1126 1127 1144 1176 1192 1204 1213 1222 1220
1245 1238 1238 1244 1247 1251 1288 1297 1289 1325 1201 1161 1141 1137 1133 1127 1124 1126 1133 1154 1187 1197 1221 1219
1247 1237 1236 1244 1249 1257 1303 1389 1331 1292 1226 1191 1152 1144 1140 1133 1126 1123 1124 1130 1149 1186 1207 1220
1249 1237 1233 1251 1271 1321 1455 1456 1422 1398 1276 1185 1152 1145 1140 1133 1125 1121 1124 1127 1144 1175 1208
1249 1239 1231 1234 1248 1271 1295 1366 1576 1548 1398 1282 1209 1166 1148 1145 1140 1131 1121 1124 1128 1143 1185
1251 1246 1231 1229 1235 1254 1281 1371 1475 1465 1530 1318 1225 1179 1158 1151 1146 1138 1126 1119 1120 1123 1127 1150
1251 1248 1234 1227 1232 1240 1320 1375 1432 1479 1346 1476 1188 1167 1162 1153 1145 1136 1121 1117 1116 1118 1122
1253 1256 1244 1228 1235 1241 1261 1291 1315 1348 1336 1304 1232 1182 1161 1162 1153 1146 1132 1116 1114 1112 1113
1251 1275 1253 1234 1226 1221 1241 1271 1294 1297 1291 1265 1227 1183 1158 1159 1162 1163 1157 1144 1122 1113 1111 1110
1251 1308 1284 1245 1226 1218 1230 1251 1274 1286 1259 1239 1218 1181 1158 1158 1163 1164 1155 1136 1113 1110 1108
0.0000000E+00 0.8985154E-02 0.5360211E-01 0.1590036E+00 0.3029266E+00
0.0000000E+00 0.3047725E-02 0.2389413E-01 0.9965295E-01 0.2277447E+00

```

Figure 1.8. Continuation of the HOTMAC input file *hot_in* illustrating the format of the landclass, elevation, and soil depth input parameters.

```

#
# -----
# SOLAR RADIATION INPUT FILE (FROM SCOTT SMITH'S WORK)
# -----
# 38 bands

 0.94   0.94   0.94   0.94   0.94
 1.10   1.10   1.10   1.10   1.10
 1.38   1.38   1.38   1.38   1.38
 1.87   1.87   1.87   1.87   1.87
 2.70   2.70   2.70   2.70   2.70
 3.20   3.20   3.20   3.20   3.20 wavelength for each H2O absorption band

 0.0003  0.0205  0.1722  1.0944  8.1860
 0.0011  0.0208  0.1514  1.0551  8.1921
 0.0042  0.0364  0.2600  1.8090  11.0836
 0.0008  0.0225  0.2386  1.8740  11.4786
 0.0062  0.0752  0.7439  6.4302  40.1905
 0.0138  0.1291  0.6186  1.6246  23.7275      gas absorption coefficients

78.7773 17.2306 6.9625 .3202 .0000
43.5223 21.7576 6.2052 .0859 .0000
36.8564 24.3795 24.9340 12.2095 .6436
24.6087 12.1855 10.2585 5.3589 .3960
11.1822 8.6607 8.2439 5.8590 1.0716
7.8905 3.3403 .5364 .1657 .0000      fractional solar flux

 9.8E-6  9.8E-6  9.8E-6  9.8E-6  9.8E-6
2.415B-5 2.415B-5 2.415B-5 2.415B-5 2.415B-5
2.152B-4 2.152B-4 2.152B-4 2.152B-4 2.152B-4
 0.001    0.001    0.001    0.001    0.001
 0.114    0.114    0.114    0.114    0.114
 0.388    0.388    0.388    0.388    0.388      c constants

 2.100E-5 2.100E-5 2.100E-5 2.100E-5 2.100E-5
 8.900E-5 8.900E-5 8.900E-5 8.900E-5 8.900E-5
 7.772B-4 7.772B-4 7.772B-4 7.772B-4 7.772B-4
 0.002    0.002    0.002    0.002    0.002
 0.007    0.007    0.007    0.007    0.007
 0.003    0.003    0.003    0.003    0.003      d constants

 0.783    0.783    0.783    0.783    0.783
 0.780    0.780    0.780    0.780    0.780
 0.756    0.756    0.756    0.756    0.756
 0.740    0.740    0.740    0.740    0.740
 0.831    0.831    0.831    0.831    0.831
 0.816    0.816    0.816    0.816    0.816      e constants

 5.035    5.035    5.035    5.035    5.035
 4.972    4.972    4.972    4.972    4.972
 6.417    6.417    6.417    6.417    6.417
 7.469    7.469    7.469    7.469    7.469
 3.556    3.556    3.556    3.556    3.556
 6.182    6.182    6.182    6.182    6.182      f constants

 0.5435   0.5435   0.5435   0.5435   0.5435
 0.5217   0.5217   0.5217   0.5217   0.5217
 0.4304   0.4304   0.4304   0.4304   0.4304
 0.6207   0.6207   0.6207   0.6207   0.6207
 0.6098   0.6098   0.6098   0.6098   0.6098
 0.5119   0.5119   0.5119   0.5119   0.5119      K/D values from Liou + Sasamori

 O3
 0.3    ozone uv band wavelength
229.433 1.0E-1 0.0000      p0t,akk,rkd (window bands)
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 O2
 0.5    ozone vis band wavelength
200.000 1.0E-1 0.0000      p0t,akk,rkd (window bands)
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 O2
 0.7    O2 band wavelength
400.000 1.0E-3 0.0000      p0t,akk,rkd (window bands)
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 WINDOW
 1.0    window band wavelength
58.832 1.0E-6 0.0000      p0t,akk,rkd
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 WINDOW
 1.23   window band wavelength
20.851 1.0E-6 0.0000      p0t,akk,rkd
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 WINDOW
 1.6    window band wavelength
37.246 1.0E-6 0.0000      p0t,akk,rkd
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 WINDOW
 2.15   window band wavelength
15.440 1.0E-6 0.0000      p0t,akk,rkd
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

 WINDOW
 4.2    window band wavelength
10.578 1.0E-6 0.0000      p0t,akk,rkd
 0.99999 0.0000 0.0000 0.0000      c, d, e, f

```

Figure 1.9. Two-stream solar radiatlon calculation input parameters.

2. Terrain Elevation Input

a. Format and Definitions.

The terrain data is input in text matrix format in the *hot_in* file as depicted in Table 2.1. The terrain heights are in meters above sea-level and are usually thought to represent an areal average over the grid cell. The lower left hand corner of the data matrix corresponds to the southwest corner of the elevation data.

Table 2.1 HOTMAC Terrain Elevation Input Format

N	2109	2109	2139	2260	2260	2197	1617	1536	1563	1705	1949	1780	1880	2000	1853	1664	1516
↑	2151	2151	2194	2426	2060	2197	1617	1536	1563	1705	1949	1780	1880	2000	1853	1664	1516
	2382	2382	2230	2370	1962	1645	1473	1485	1486	1854	1837	1687	1922	2014	1820	1649	1514
	2319	2319	2175	2198	2035	1470	1422	1444	1455	1742	1528	1601	1944	2099	2173	1786	1496
	2250	2354	2157	1906	1713	1474	1445	1486	1588	1445	1397	1759	2490	2066	1887	1716	1519
	2220	2463	2063	1756	1493	1444	1502	1830	1716	1289	1318	1686	2324	2236	1989	1715	1559
	2327	2507	2017	1669	1401	1461	1516	1857	1365	1227	1276	1543	2268	2362	2029	1761	1578
	1980	2292	2084	1602	1447	1561	1423	1659	1417	1205	1248	1465	2412	2364	1987	1705	1528
	1890	1870	1944	1556	1345	1438	1358	1471	1488	1204	1227	1466	2645	2355	2016	1693	1524
	1633	1655	1716	1493	1377	1363	1326	1360	1594	1216	1213	1266	2006	2219	1919	1756	1610
	1449	1479	1546	1403	1472	1504	1330	1357	1602	1218	1266	1281	1573	1695	1722	1603	1870
	1387	1367	1319	1291	1365	1380	1309	1286	1634	1225	1254	1367	1548	1417	1429	1297	1382
	1323	1307	1396	1257	1286	1339	1286	1210	1296	1231	1266	1480	1560	1461	1332	1250	1210
	1391	1316	1314	1233	1339	1382	1277	1220	1300	1227	1281	1603	1547	1541	1309	1156	1107
	1410	1319	1288	1220	1280	1291	1261	1239	1264	1203	1271	1540	1526	1389	1307	1158	1102
	1522	1302	1266	1218	1208	1240	1241	1247	1283	1140	1220	1346	1474	1403	1286	1229	1145
	1274	1354	1241	1210	1193	1204	1222	1247	1236	1186	1141	1222	1409	1479	1354	1368	1475
	1289	1376	1347	1203	1262	1186	1206	1233	1286	1359	1197	1127	1204	1391	1423	1453	1578
	1296	1389	1425	1256	1263	1216	1185	1221	1307	1445	1354	1377	1104	1280	1421	1437	1552
S	1317	1341	1605	1240	1252	1256	1179	1227	1355	1427	1466	1542	1256	1134	1330	1341	1352

The number of elements in the N-S and the W-E directions is defined by ($imax + 3$) and ($jmax + 3$), respectively, while the spacing of the data points (or grid cell size) is determined by $xintvl$ and $yintvl$. Note that an extra strip of topography grid cells is required around the computational mesh due to the need for computing terrain slopes within HOTMAC. As will be shown in the next section, only ($imax + 1$) and ($jmax + 1$) grid cells are used for the landclass input in the *hot_in* file.

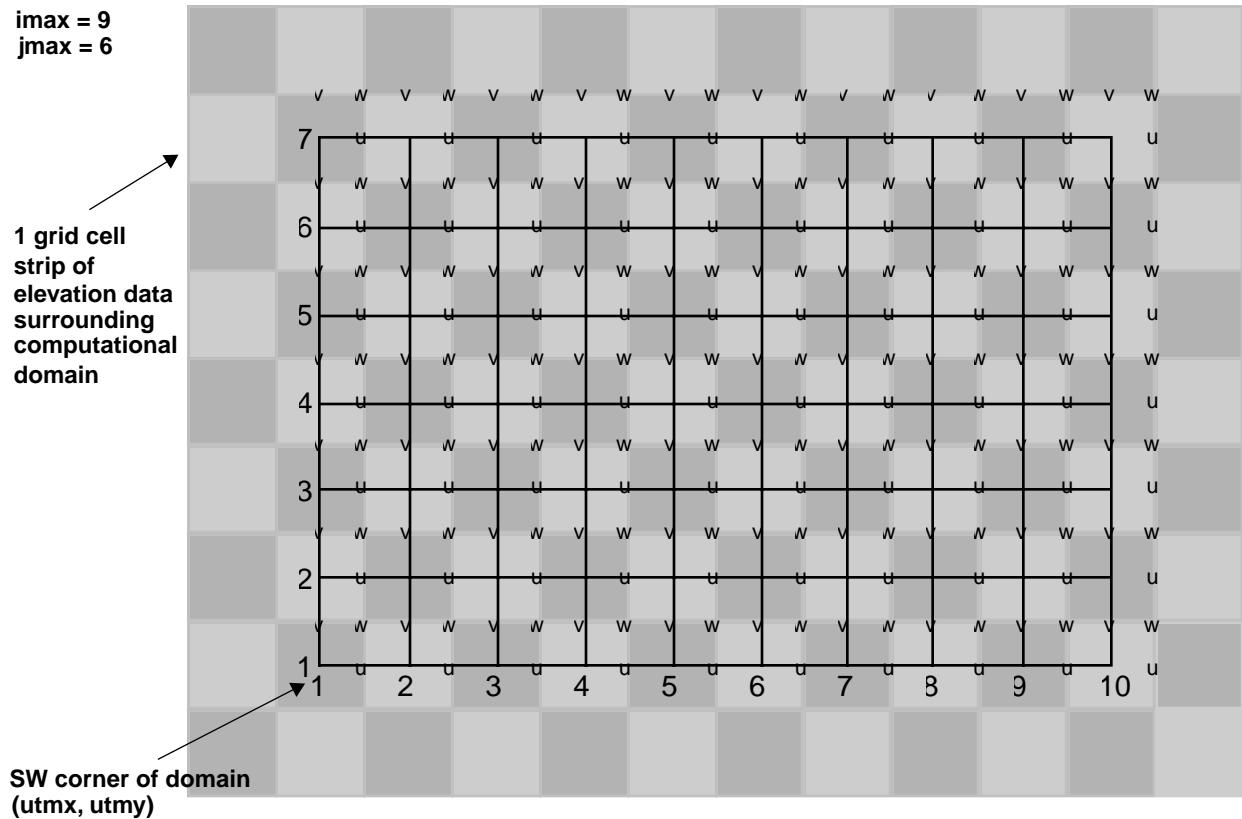


Figure 2.1 Relationship between the topographical data cells (gray boxes), the computational mesh (black lines), and the wind field variables u , v , and w . Notice that the SW corner of the domain defined in the ***hot_in*** file is for the computational mesh, but the topography data extends $1\frac{1}{2}$ grid cells on all sides beyond the computational mesh.

Figure 2.1 shows the relationship between the topography data and the computational mesh. The topography cells are centered at the computational grid cell vertices. The u , v , and w wind components are calculated at staggered points as shown. Notice that the numbering goes from $i = 1$ to $imax$ from west to east and from $j=1$ to $jmax$ from south to north. Notice also that the southwest corner of the topographical mesh is not equivalent to the southwest corner of the computational mesh (the latter defined by utm_x and utm_y).

b. Data Acquisition and Processing.

The elevation data needs to be in the format shown in Table 2.1 in order to be read in correctly by HOTMAC. Although there are several topographical data sources, we currently obtain our data from the USGS via the internet. For the USA, 3 arcsecond resolution

DEM (digital elevation model) data organized by 1:250,000-scale quadrangles is available for download at no cost using the file transfer protocol (ftp) or a web browser. For the rest of the world, the USGS has freely-available 30 arcsecond data available by ftp (edcftp.cr.usgs.gov) or off the web (<http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html>). The procedure for obtaining the US 3 arcsecond data via ftp is:

1. ftp to the server: "ftp edcftp.cr.usgs.gov"
2. enter "anonymous" at the name prompt
3. enter your e-mail address at the password prompt
4. go to the landclass directory ("cd /pub/data/DEM/250") where you will find an alphabetical directory listing
5. go to the appropriate directory, e.g., "cd /A/albuquerque-e.gz" (files are organized alphabetically by 1 degree by 1 degree quad name)
6. set the file transfer mode to binary: "bin"
7. download the README and desired data files using the "get" or "mget" commands (note: if the extension ".gz" is typed at the end of the filename, the file will be downloaded as a compressed GNU gzip file; without the extension, the file will be decompressed before downloading)

The method for obtaining data using a web browser (e.g., Netscape, Mosaic) is:

1. within the browser open the site: "<http://edcwww.cr.usgs.gov/doc/edchome/ndcddb/ndcddb.html>"
2. scroll down the page to the header "1:250,000-Scale Digital Elevation Model (DEM)"
3. read the online user guides
4. click on either "FTP via Alphabetical List", "FTP via State", or "FTP via -Graphics"
- 5a. for the first ftp option, go to the appropriate subdirectory, e.g., double-click first on "/A", then "aberdeen-e.gz" (files are organized by alphabetically by 1 degree by 1 degree quad name)
- 5b. for the second ftp option, go to the appropriate subdirectory, e.g., double-click on "/Alabama", scroll down the list until the appropriate quad name is found, and then double-click on either "compressed" or "decompressed" to download the file
- 5c. for the third ftp option, zoom in on the desired region of the US map image, double-click on the appropriate quad, then on the quad name, and finally on the appropriate file

Once the appropriate files are downloaded, we use the **gunzip** utility (available by ftp from "prep.ai.mit.edu:/pub/gnu" or "wuarchive.wustl.edu:/systems/gnu") to decompress the files if necessary. The files need delimiters added and the appropriate command on

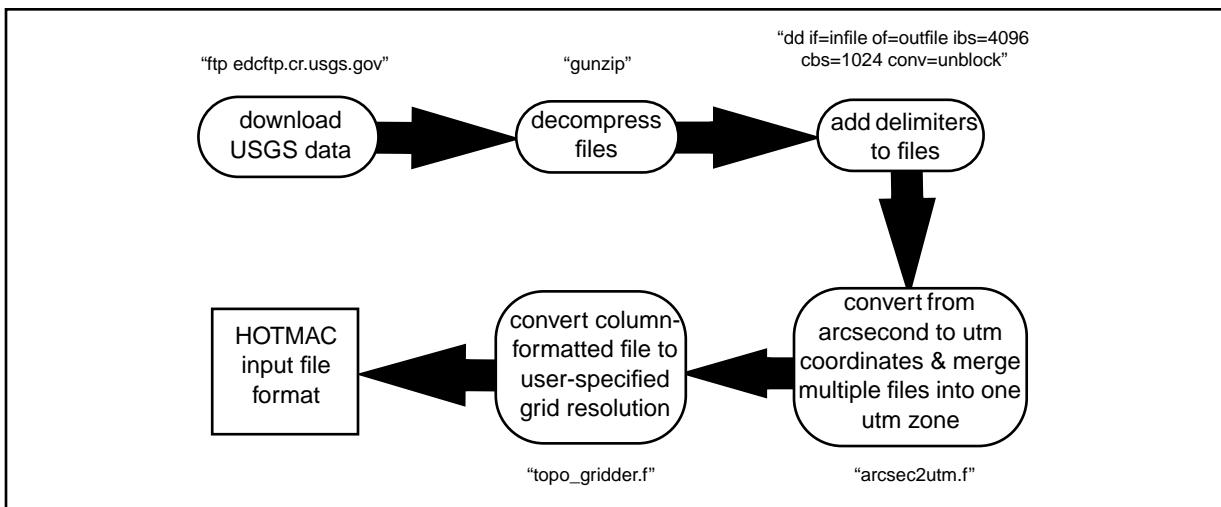


Figure 2.2 Flowchart of procedure for changing USGS topographical data into HOTMAC- formatted elevation data.

a Unix-based system is “*dd if=input filename of=output filename ibs=4096 cbs=1024 conv=unblock*”. There is a downloadable program on the USGS website for adding delimiters on PC-based computers; we are not sure how to add delimiters on a Mac-based computer.

As shown in fig. 2.2, the files are now ready to be read into the “**arcsec2utm**” FORTRAN program, which will convert the data from the USGS latitude-longitude format to an ascii-text three column format. One input file is required that lists the names of each USGS quadrangle file that will be read in (the list order of the quadrangle files is not important, but the file names should be listed sequentially one file name per row). Two output files are produced: one containing elevation, latitude and longitude and the other elevation, utmx, and utmy. If the quadrangle files cover more than one utm zone (the utm zones are in 6 degree wide longitudinal bands around the globe, each with their own utm coordinate frame of reference), the **arcsec2utm** program prompts the user to specify which zone should be used for the utm coordinate frame of reference. The read-in spacing of the data is user-specified in the **arcsec2utm** program and is limited to integer multiples of 3 arcseconds. We recommend setting the read-in spacing at least 3-5 times higher than the resolution of the HOTMAC simulation grid(s). Note that the 3 arcsecond datapoints are spaced at approximately 100 meter intervals for mid-latitudes.

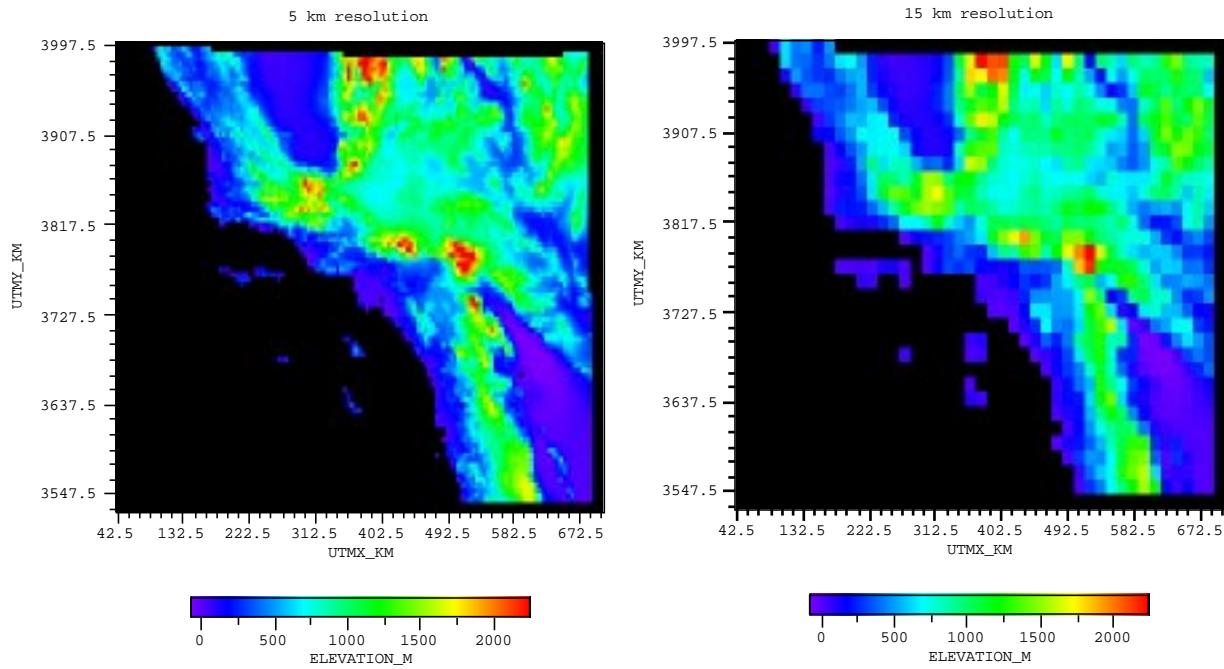


Figure 2.3. a) Map of southern California created from USGS data using 60 arcsecond resolution with **arcsec2utm** and 5.0 km resolution with **topo_gridder**. b) 15 km resolution HOTMAC outergrid created with **topo_gridder**. Note that the ocean option is off, so that land area is most likely overestimated.

Since the elevation data in the utm coordinate system is irregularly spaced, one must interpolate the data to an equally-spaced rectilinear grid. We use a FORTRAN program called **topo_gridder** to average the elevation data over user-specified grid cells of size *xintvl* and *yintvl* (see fig. 2.3). For coastal environments, the user can set an option that interprets 0.000 data values as ocean. For grid cells with a majority of 0.000 data values the program will then set the grid cell elevation value to 0.000. This tends to improve the coastline interpretation, however, we encourage users to check the landclass and elevation grid cell values in order to ensure consistency. The **topo_gridder** program outputs the topography data in HOTMAC format. The program also outputs the number of datapoints used, the standard deviation of the elevation, and the fraction of ocean (0.000 values) for each grid cell. Note that a commercial program, such as Fortner Transform, could be used for averaging the relatively high resolution elevation data for use by HOTMAC, but care must be taken to ensure that the averaging routines correctly interpret data values and locations.

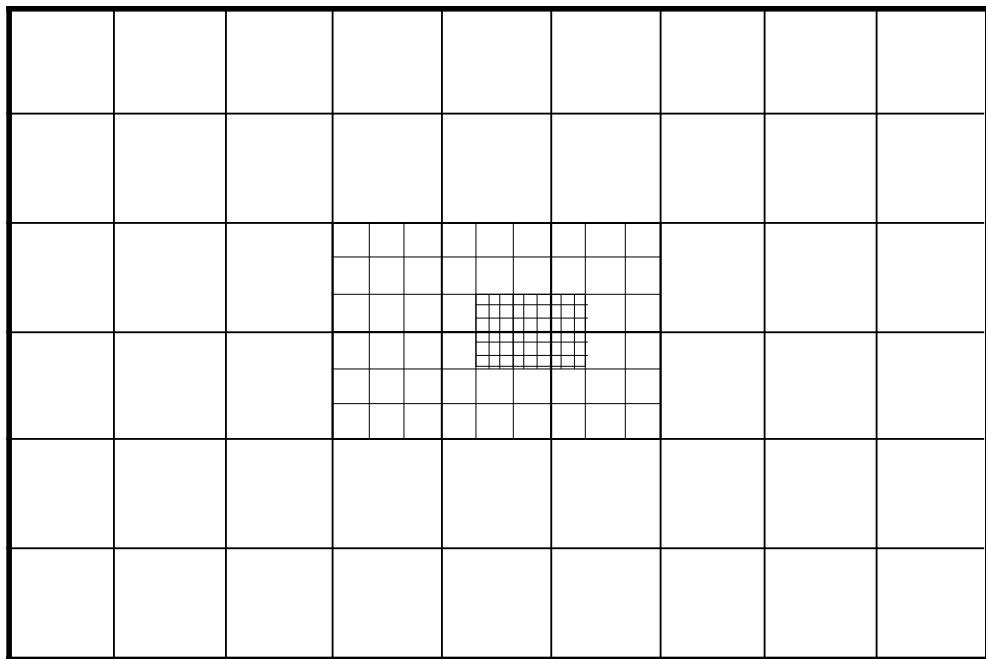


Figure 2.4. Setup of nested computational meshes. In this example, the number of grid meshes *ngmax* is 3 and the grid size ratio between nested meshes *grid_ratio* is 3. Note that SW and NE corners of the inner meshes align exactly with the grid cell edges of the next-most outer mesh.

c. Nested Grid Set-up.

HOTMAC simulations are typically performed using nested grids. Setting up the elevation grid matrices for nested meshes imposes conditions on the southwest corner locations and the size of each computational grid mesh. For example, for a simulation using three grid meshes (*ngmax*=3), the southwest corner (*utmx* and *utmy*) of the intermediate resolution mesh must fall directly on a node of the coarse resolution mesh, and likewise the southwest corner of the fine resolution mesh must fall directly on a node of the intermediate resolution mesh (see fig. 2.4). Additionally, the northeast corners of the intermediate and fine meshes must fall directly on nodes of the coarse and intermediate meshes, respectively (see fig. 2.4). The southwest corner of each grid mesh is set at the beginning of the ***hot_in*** input file with *utmx* and *utmy* in the “nest” namelist. The northeast corner of each grid mesh is controlled by the grid spacing (*xintvl* and *yintvl* in the “grid” namelist), the number of grid cells in the E-W and N-S directions (*imax* and *jmax* in the “grid” namelist), and the grid size ratio between nested meshes (*grid_ratio* in the

“nest” namelist).

3. Landclass Input

a. Format and Definitions.

In HOTMAC, landclass information is used in the determination of the surface radiation balance, as well as for parameterizations of the surface drag and turbulent kinetic energy. The landclasses are input in text matrix format in the ***hot_in*** file as shown below.

Table 3.1 HOTMAC Landclass Input Format

N	7	7	7	7	7	11	9	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	11	11	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	11	11	11	11	11	11
	9	9	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	11	11	11	11	11	11
	9	9	11	11	11	11	11	11	11	11	11	11	11	9	9	9	9	9	9	9	9	11	11
	11	11	11	11	11	11	9	11	11	11	11	11	11	9	11	11	11	11	11	11	11	11	11
	11	11	11	12	11	11	9	11	11	11	11	11	11	9	11	11	11	11	11	11	11	11	11
	11	11	11	11	9	9	9	11	9	11	9	9	9	9	9	11	9	11	11	11	11	11	11
	11	11	6	11	12	9	9	9	9	11	9	9	9	9	9	9	9	9	11	11	11	11	11
	11	11	6	11	11	9	9	9	9	9	9	9	9	9	9	9	9	9	11	9	9	9	9
	11	6	6	11	12	12	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	11	6	6	6	11	9	9	9	9	9	9	9	9	9	9	9	9	11	9	9	9	9	9
	11	11	6	6	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	11	9	9	9	9	12	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	11	9	9	9	9	9	7	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	11
	11	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	11	9	9	9	9	11	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	2	9	9	7	11	11	9	9	9	9	9	9	9	9	9	9	9	9	9	11	11	9	
	9	6	11	11	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	11	9	
S	9	9	9	9	9	9	6	9	9	9	9	9	9	9	12	12	9	9	9	9	9	9	
																							E

The data goes from North to South from top to bottom and from West to East from left to right. Parameters governing the size of the data matrix (*imax* and *jmax*), the spacing of data points (*xintvl* and *yintvl*), and the southwest corner of the matrix (*utmx*, *utmy*, *ibgn*, *jbgn*) are found at the beginning of the file ***hot_in***. The landclass data are centered on the same grid points as the elevation data (see fig. 2.1), the only difference being that the extra strip of grid cells along the perimeter of the elevation grids is not needed in this case. Note: the landclass matrix is of size *imax* + 1 by *jmax* + 1.

The 14 landclass categories used by HOTMAC are defined below in Table 3.2. For each

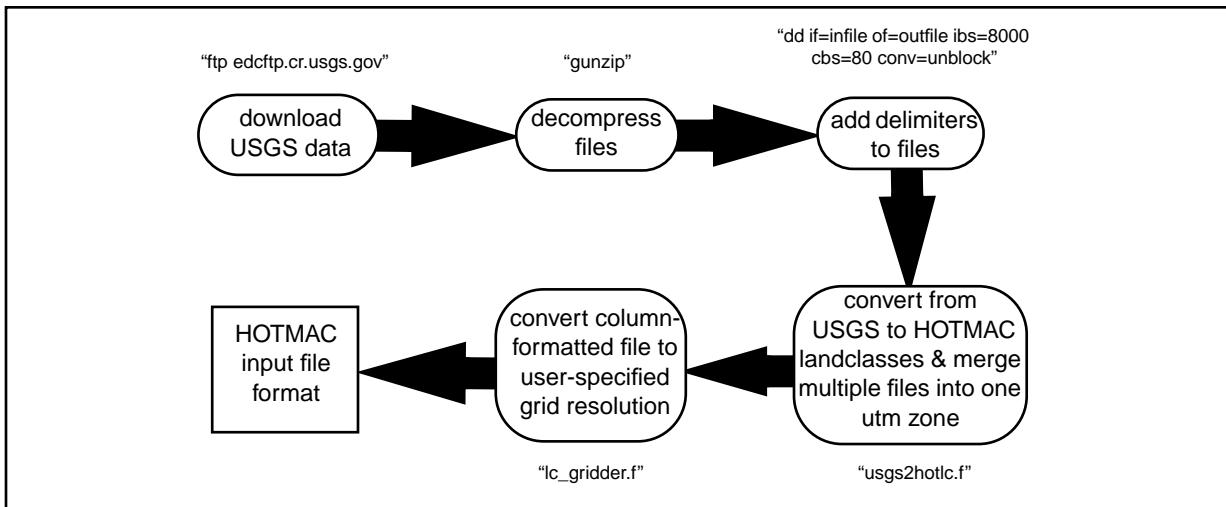


Figure 3.1 Flowchart of procedure for changing USGS landclass data into HOTMAC-formatted landclass data.

landclass, the density (*rhosc*), specific heat (*csc*), thermal diffusivity (*edksc*), bowen ratio (*bowdy*), albedo (*albedc*), and emissivity (*emissc*) are given, as well as forest and urban canopy parameters. These properties are specified in the HOTMAC subroutine ***initia*** as data statements. At this time, the roughness length is assumed constant over the entire HOTMAC modeling domain. The breakdown of the urban landclasses (residential, industrial/commercial, and downtown/city center) and the sand landclass are new to HOTMAC version 4.

b. Data Acquisition and Processing.

The landclass data need to be in the format shown in Table 3.1 in order to be used by HOTMAC. Although there are several landclass data sources, we currently obtain our data from the USGS via the internet. For the USA, 200 m resolution landclass datasets are available for download at no cost using the file transfer protocol (ftp) or a web browser. (For the rest of the world, we have used ad-hoc approaches, sometimes digitizing from commercially-available paper land maps, satellite land-use maps, or CD-Rom products).

As depicted in fig. 3.1, the USGS-obtained landclass data goes through a mult-stage reformatting process in order to get it into the desired HOTMAC format. The procedure

Table 3.2 HOTMAC Landclass Properties

for obtaining data via ftp is:

1. ftp to the server: "ftp edcftp.cr.usgs.gov"
2. enter "anonymous" at the name prompt
3. enter your e-mail address at the password prompt
4. go to the landclass directory ("cd /pub/data/LULC/250K") where you will find an alphabetical directory listing
5. go to the appropriate directory, e.g., "cd /A/aztec" (files are organized alphabetically by quad name)
6. set the file transfer mode to binary: "bin"
7. download the README and desired data files (named grid_cell.gz) using the "get" or "mget" commands (note: if the extension ".gz" is typed at the end of the filename, the file will be downloaded as a compressed GNU gzip file; without the extension, the file will be decompressed before downloading)

The method for obtaining data using a web browser (e.g., Netscape, Mosaic) is:

1. within the browser open the site: "<http://edcwww.cr.usgs.gov/doc/edchome/ndcldb/ndcldb.html>"
2. scroll down the page to the header "1:250,000-Scale and 1:100,000-Scale Land Use and Land Cover (LULC)"
3. read the online user guides
4. click on either "250K FTP via Alphabetical List", "250K FTP via State", or "250K via -Graphics"
- 5a. for the first ftp option, go to the appropriate subdirectory, e.g., double-click first on "/A", then "/aztec" (files are organized by alphabetically by quad name) and finally on "grid_cell.gz"
- 5b. for the second ftp option, go to the appropriate subdirectory, e.g., double-click on "/Alabama", scroll down the list until the appropriate quad name is found, and then under grid_cell double-click on either "compressed" or "decompressed"
- 5c. for the third ftp option, zoom in on the desired region of the US map image, double-click on the appropriate quad, then on the quad name, and finally on the "grid_cell.gz" file

Once the appropriate files are downloaded, use the **gunzip** utility (available by ftp from "prep.ai.mit.edu:/pub/gnu" or "wuarchive.wustl.edu:/systems/gnu") to decompress the files if necessary. The files need delimiters added and the appropriate command on a Unix-based system is "dd if=*input filename* of=*output filename* ibs=8000 cbs=80 conv=unblock". We are not sure how to add delimiters on PC- and Mac-based computers.

The files are then read into the "**usgs2hotlc**" program which converts the USGS land-

```

# INPUT FILE FOR usgs2hotlc
# (note: comments below must occur after column 30)
5                               ! NO. OF QUADS (FILES) TO READ IN
Abilene.lc                      ! INPUT FILE NAME
Ardmore.lc
Brownwood.lc
Dallas.lc
Tyler.lc

```

Figure 3.2. Example of the input file ***usgs2hotlc.input*** illustrating the required format. Note that the first two lines are for comments.

classes to HOTMAC landclasses (see Table 3.3). An input file called ***usgs2hotlc.input*** listing all the landclass file names is required, an example of which is provided in Fig. 3.2. If the map files that are read in are from more than one utm zone, the program changes the utm coordinate values to a user-specified utm zone (the utm zones are in 6 degree wide longitudinal bands around the globe, each with their own utm coordinate frame of reference). An output file is produced with utmx, utmy, USGS landclass, and HOTMAC landclass data in column format.

This output file is then read by the “**lc_gridder**” program which converts the column-formatted data to HOTMAC text matrix format using user-specified grid resolution and domain bounds. The program counts the different landclass types in each HOTMAC grid and gives the grid cell the landclass value of the most frequently occurring value. The text matrix formatted landclass data can be copied from the output file and pasted directly into the ***hot_in*** HOTMAC input file.

We also have a series of programs called “**lc2hot_1**”, “**lc2hot_2**”, “**lc2hot_2b**”, and “**lc2hot_3**” which will convert the USGS landclasses to HOTMAC landclasses in smaller steps, useful for analyzing intermediate results. Input files called ***program_name.input*** are required for each program. The “**lc2hot_1**” program produces two output files containing the USGS and HOTMAC landclasses in text matrix format with 200 m grid spacing. The program **lc2hot_2** converts the files from 200 m grid spacing to 1 km grid spacing using 25 cells for averaging. The program **lc2hot_2b** is used to convert the utm

Table 3.3 Mapping of USGS to HOTMAC Landclasses

USGS LC#		USGS LC Type	HOTMAC LC
URBAN			all to (9) urban mixture
1 (11)	residential		to (5) urban residential
2 (12)	commerical and services		to (8) urban industrial/commercial or (9)
3 (13)	industrial		to (8) urban industrial/commercial
4 (14)	transportation and communication		to (10) urban roads
5 (15)	industrial and commercial		to (8) urban industrial/commercial
6 (16)	mixed urban (combination of above)		to (8) urban industrial/commercial
7 (17)	other urban (golf courses, parks, ski areas)		to (1) low moist vegetation
AGRICULTURAL LAND			
8 (21)	cropland and pasture		to (1) low moist vegetation
9 (22)	orchards/groves/vineyards/nursuries		to (11) tall moist vegetation
10 (23)	confined feeding operations		to (3) dark moist soil
11 (24)	other agricultural land		to (1) low moist vegetation
RANGELAND			all to (6) vegetation and scrubland
12 (31)	herbaceous rangeland		
13 (32)	shrub and brush rangeland		
14 (33)	mixed rangeland		
FOREST LAND			all to (12) mtn.vegetation (conifers)
15 (41)	deciduous forest land		
16 (42)	evergreen forest land		
17 (43)	mixed forest land		
WATER			all to (7) water
18 (51)	streams and canals		
19 (52)	lakes		
20 (53)	reservoirs		
21 (54)	bays and estuaries		
WETLAND			
22 (61)	forested wetlands		to (11) tall moist vegetation
23 (62)	nonforested wetlands		to (1) low moist vegetation
BARREN LAND			
24 (71)	dry salt flats		to (14) sand
25 (72)	beaches		to (14) sand
26 (73)	sandy areas other than beaches		to (14) sand
27 (74)	bare exposed rock		to (4) rock (basalt)
28 (75)	strip mines/ quarries/gravel pits		to (4) rock (basalt)
29 (76)	transitional areas		(2) bare dry soil
30 (77)	mixed barren land		(2) bare dry soil
(8)	TUNDRA		no match; for now (2) bare soil
(9)	PERENNIAL SNOWFIELDS		no match; for now missing data

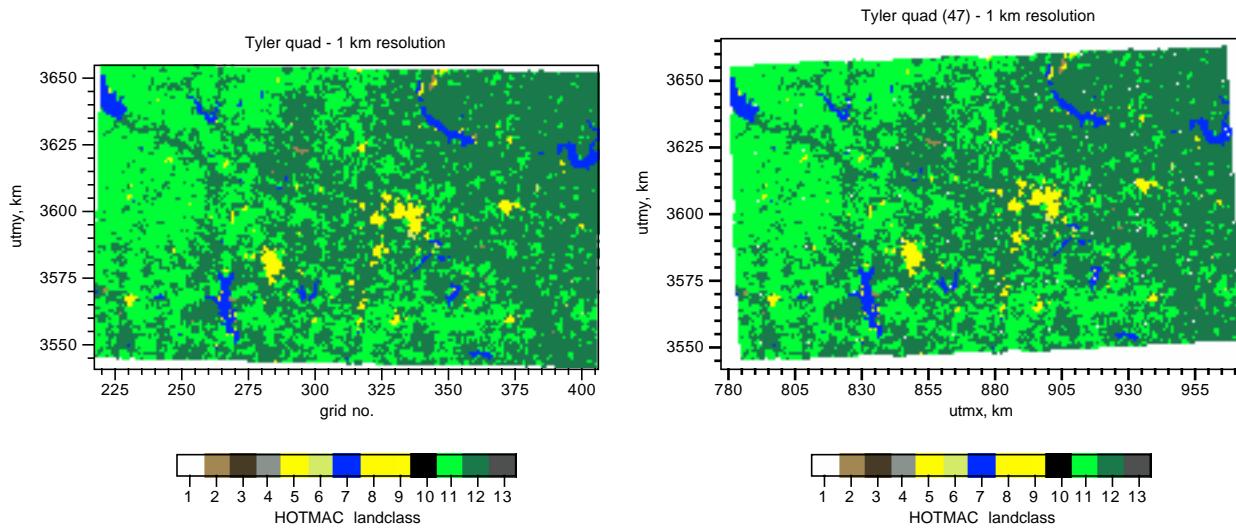


Figure 3.3. Converting the Tyler Quad landclass file from utm zone no. 46 to utm zone no. 47 using **lc2hot_2b**. Note: the (14) sandy soils landclass is not shown.

coordinates of all the files to the same utm zone. Figure 3.3 shows an example of a file being converted from one utm zone to another. The program **lc2hot_3** is used to convert the files from 1 km grid spacing to user-specified grid spacing (at this time, the grid-spacing is limited to even integer values) and to set the bounds of the domain.

c. USGS-HOTMAC Landclass Mapping Assumptions.

The mapping between the USGS and HOTMAC landclasses (Table 3.2) contains uncertainties due to ambiguities in the landclass definitions, temporal variability in surface properties for a given landclass, and the small number of HOTMAC landclass types. A qualitative description of how the different USGS landclasses are classified is contained in Anderson et al. (1976) and one can see from this document that there is some subjectivity in the USGS land classification scheme.

The HOTMAC urban landclasses are divided into (5) “urban residential”, (8) “urban industrial/commercial”, (9) “urban downtown/city center”, and (10) “roads” which are meant to correspond roughly to areas with high vegetation fraction/short buildings, low vegetation fraction/short buildings, low vegetation fraction/tall buildings, and low vegetation fraction/no buildings, respectively. From the USGS urban landclass types, however, it is not possible to conclude whether the buildings are tall, thus no USGS urban land-

classes are mapped to the HOTMAC (9) “urban downtown/city center” landclass by the “**usgs2hotlc**” program. Furthermore, the USGS (17) “other urban or built-up land” is mapped to the HOTMAC (1) low moist vegetation landclass since it is supposed to contain urban parks, golf courses, and ski areas.

Currently, we assume that the USGS agricultural landclasses are moist (low bowen ratios) and therefore map to moist HOTMAC landclass types (e.g., (1) “low moist vegetation”, (3) “dark moist soil”, (11) “tall moist vegetation”). However, it is clear that the USGS agricultural landclasses could be dry dependent on irrigation practices, climate, and other factors. The USGS rangeland landclasses are all mapped to the HOTMAC (6) “scrubland” landclass which is assumed to be dry. Again, it is clear that scrubland could intermittently be wet dependent on climate and other factors.

We assume that the USGS (22) “orchards, groves, vineyards, nurseries” and (61) “forested wetlands” landclasses contain a tree canopy and are therefore mapped to the HOTMAC (11) “tall moist vegetation” landclass. Note that the HOTMAC (6) “scrubland” landclass is also assumed to have a low tree canopy.